BELL LABORATORIES RECORD

BURIED TELEPHONE WIRE
D. A. QUARLES

FIVE-KILOWATT RADIO TRANSMITTER
L. G. YOUNG

CIRCUIT PROTECTION AT POWER STATIONS
L. L. LOCKROW

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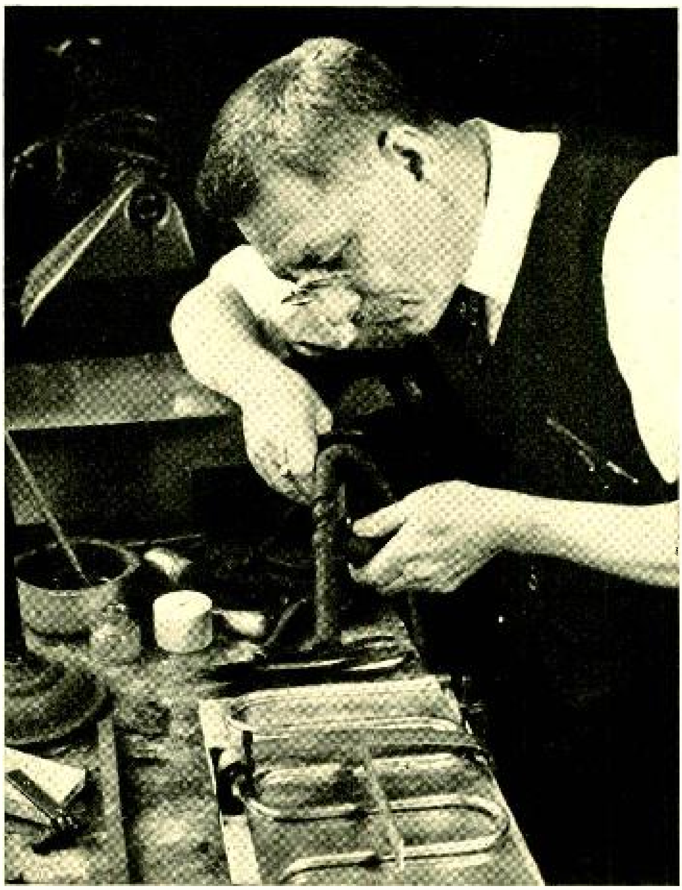

Soldering a cooling coil into place on the wall of a constant-temperature box

NOVEMBER, 1936

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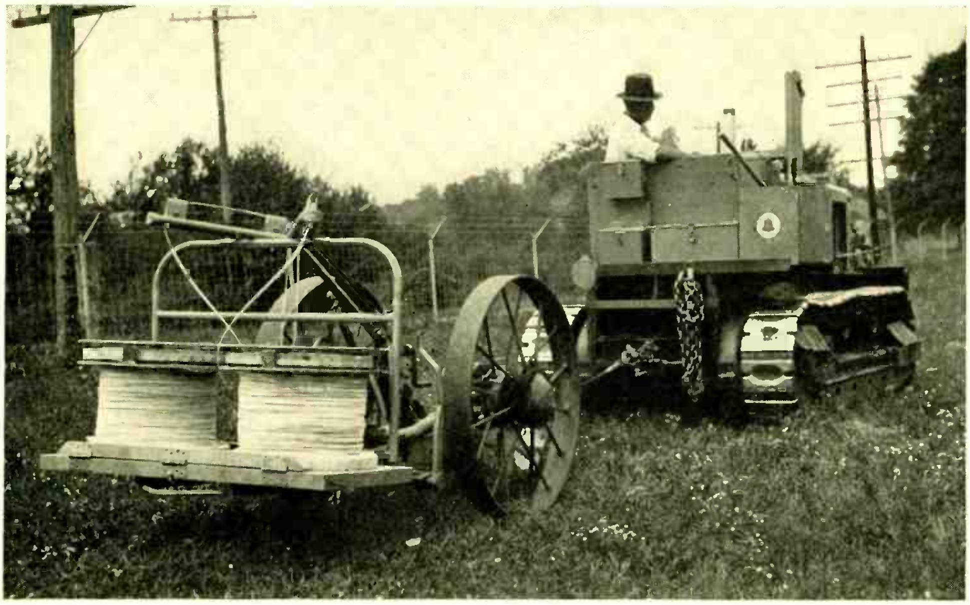


Buried Telephone Wire

By D. A. QUARLES
Outside Plant Development Director

THE urge to put telephone lines under ground is only a little younger than the business itself. In some measure, this has been realized by installing lead-covered cables in conduit that had previously been placed in the ground. As a further move in this direction, the Bell System some years ago buried its first tape-armored toll cable* directly in the ground; and where conditions have been favorable, this practice has since been extended to large and small exchange-area cables and to one and two-pair entrance cables for underground service connections. All such cables, however, have been lead covered and protected from sheath corrosion by successive layers of paper and jute impregnated with asphalts. In the armored form, steel tapes are added as a provision against interference from outside electrical sources.

Because the cost of underground cables in conduits and of buried cables essentially limits their use to those cases where appearance is important or where a considerable number of circuits can be grouped under the same sheath, these methods are not generally applicable to service on one, or two, circuit routes, such as those extending to remote subscribers, typical of rural distribution. Primarily in the interest of providing a lower cost type of plant and thereby making possible a more extensive use of service in rural communities the development of an inexpensive form of buried circuit was undertaken. To be successful it was obviously required that an economical means of installation be devised and—even more important—

*RECORD, *June*, 1930, *p.* 465.

that the material used be serviceable for a long period under the severe moisture conditions to which it would be subjected in the ground.

Experience with cable burial had led to the development of a cable-laying plow, the neat operation of which in plowing cable into the ground at depths ranging up to thirty inches without trenching or back-filling in the ordinary sense has been described elsewhere. The adaptation of this method to the burial of wire at an appropriate depth required that it be simplified so that it would be less expensive. It involved as considerations the very much smaller size and tensile strength of the wire, its greater vulnerability to mechanical injury, and the need for reducing and simplifying traction requirements.

On the point of serviceability, it remained for the research chemists to solve an important part of the problem by the development in Bell Telephone Laboratories of a rubber compound that could be used to insulate a pair of wires and could be relied on to maintain suitable insulating properties over a period of years under the severe moisture conditions that are encountered under ground.

With these fundamentals in hand, the development engineers undertook to study the mechanical and electrical problems involved and to design a wire that would have appropriate transmission and handling characteristics. In addition, they had to devise methods of splicing the wire; to adapt plow equipment to its installation; to develop loading arrangements for use on the longer lengths; to study methods of tracing the path of the wire for the purpose of locating faults. In short, the job was to develop buried wire as a practicable plant instrumentality.

The wire as actually made employs annealed copper conductors, insulated in parallel twin construction with the special rubber compound. The wire is adapted to a continuous process of extrusion and vulcanization by the Western Electric method. In common with most high-grade rubber insulating compounds, however, the insulation is quite sensitive to sunlight so that it must be carefully guarded from any unnecessary exposure to direct rays of the sun and from any extended exposure to indirect rays.

One of the principal problems in using a wire of this kind is that of splicing, since the splice must be essentially as resistant to water absorption as the wire itself. In the splice as actually developed, Figure 1, the conductor joint is made by pressing a cylindrical sleeve on the abutted ends of the wires to be joined, in this way producing a tight joint of high electrical efficiency which is relatively immune to corrosion. The joints in the two wires are staggered and the whole is encased in a pad of unvulcanized rubber which is pressed in place and vulcanized in an electrically-heated mold as shown in Figure 2. The vulcanizer is equipped with a thermostatic device to insure proper control of the temperature. This splice is intended for burial directly in the ground without other protection; and tests indicate it to be the equivalent of the unspliced wire.

While the transmission requirements to be placed on a buried circuit will depend upon the facilities with which it is associated, it is expected that buried circuits up to about five miles in length will, in general, not require loading. Where loading is necessary, provision has been made for it in the form of a permalloy dust-core coil which is individually potted with rubber insulated lead-out wires. It is intended to be spliced into the wire at 8,000-foot intervals and buried directly in the ground with the wire.

The potting arangement for the buried wire coil, Figure 3, has several features of interest. The loading coil is first potted in a small metal container which is vacuum impregnated with a moisture-resistant compound. The lead-out wires from this container are then spliced to stub lengths of the buried wire, as shown in the illustration. This container is then placed in a larger sheet copper container, from which the rubber insulated wires are brought out through tubes soldered into the copper container and pressed down into intimate contact with the rubber insulation. The lead-out wires are taped for reinforcement at the outer ends of the tubes. This outer can is then filled with a moistureproof compound and given a dip coating of moistureproof enamel. The operation of splicing the loading coil into the line wire then involves making two line wire splices.

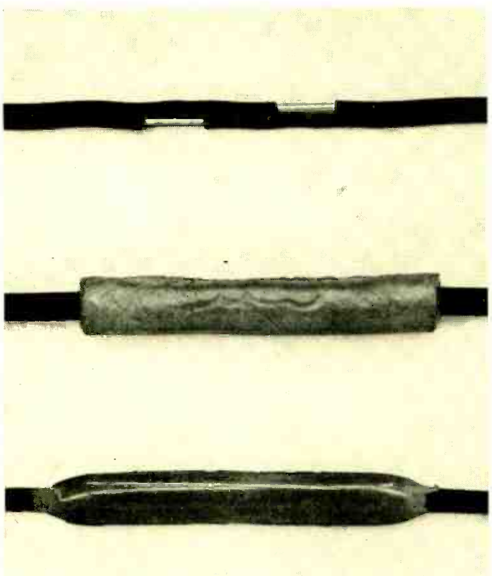


Fig. 1—Splicing buried wire. (Top) pressed sleeve joints in conductors, (center) with the unvulcanized rubber pad in place, (bottom) the splice after vulcanization

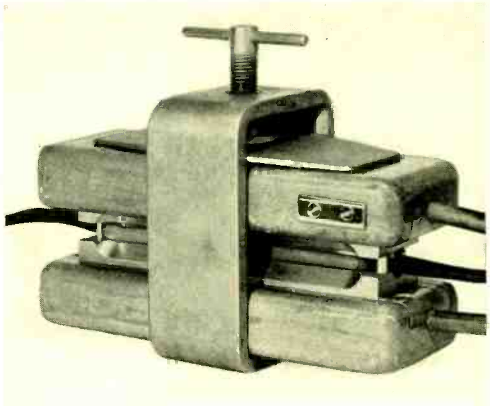


Fig. 2—Vulcanizer for buried wire splice. The buried wire is in the center and storage battery leads for heating vulcanizer are above and below on right

As mentioned above, the success of buried wire is in considerable measure dependent upon the efficiency of the equipment provided for plowing it into the ground. This problem has therefore been studied carefully with a view to reducing the traction requirements to a minimum for the desired depth of placing, so as to permit the use of readily available tractive equipment. Experiments have indicated that in a given type of soil the tractive load on the plow increases approximately as the square of the depth of setting. The choice of depth may be influenced somewhat by the local conditions, but in general it is felt that depths between sixteen and twenty inches should be adequate for normal locations and that shallower installations are only justified under special circumstances.

The plow equipment which has been developed for this purpose is shown in the headpiece. The plowshare, which is shown in Figure 4, is a vertical blade with a tube fastened to the back edge through which one or two pairs of wires may be fed into the soil. The depth of the blade in the ground is adjustable to meet local conditions. It has been found that in fairly hard soil with a liberal supply of rock, an equivalent of a 40 or 50 hp caterpillar tractor is required to draw the plow. Across stretches of private right-of-way or at other locations where it is not convenient to use tractors or trucks in direct traction, however, alternative methods have been employed, such as using the winch line of a construction truck to pull the plow. The speed at which the plow may be operated is controlled largely by the number and character of obstacles encountered. Under favorable conditions, the plow may be operated at a speed of three or four miles an hour but a much lower average is to be expected.

One consideration of some importance in installing wire of this type is the possibility of the insulation being crushed by boulders displaced by the plow, particularly where the trench with wire in place is to be rolled down or subjected to heavy traffic. This danger is, in fact, of such importance that buried telephone wire of this type is probably not a serviceable form of construction for use through a terrain where nested boulders are frequently encountered.

While it is generally possible to plow across gravel highways, this method can not be used when hard surface highways are encountered, and in such cases it becomes necessary either to use a pipe pushed under the roadway or to span the highway with open wire. Where conditions are such as to require routing the wire through or over culverts, across ditches, streams and the like, involving actual or potential exposure of the wire as by soil erosion, iron pipe or equivalent protection against mechanical injury and light will generally be required.

As in the case of other types of telephone circuits, the problem of avoiding noise and crosstalk must be considered. When more than one pair is laid in the same trench, experience has shown that twisting the wires every few feet, either in the process of removing the wire from the reels or by

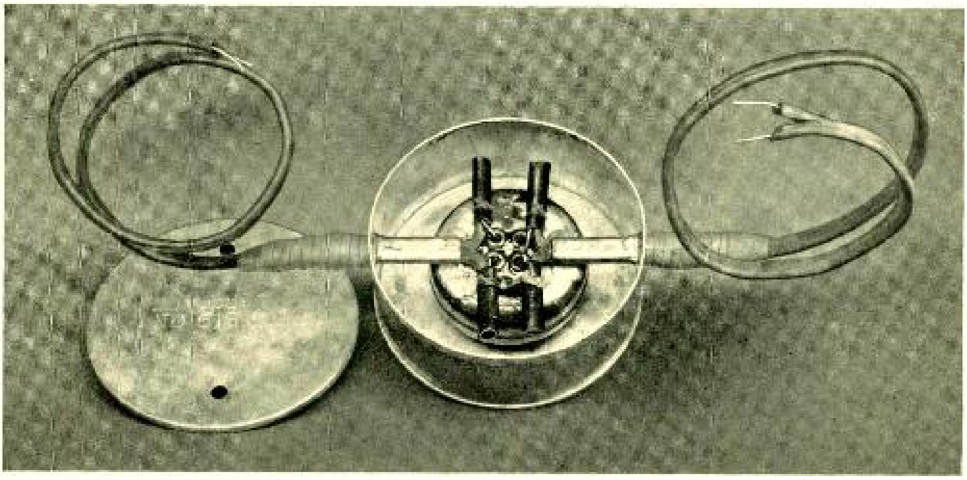


Fig. 3—Load coil for buried wire before filling outer case, showing the splicing of the rubber covered stubs to the lead-out wires from the inner case

having it pretwisted, will reduce crosstalk to satisfactorily low values.

Special care must be given the wire in manufacture to assure a good degree of balance between the capacitances of the two conductors to ground. This is important in order to avoid noise in the buried-wire circuits when they are exposed to power circuits or when the connected open wire is exposed. Under severe exposure conditions, even with the best balance obtainable in manufacture, it may be necessary to resort to special balancing measures in the field to assure satisfactorily quiet circuits.

The introduction of a new type of plant such as buried wire will naturally involve some new maintenance problems. Even though records are kept of wire routes, it will at times be desirable to have fairly precise methods of tracing the underground path. Experiments have indicated that this may be done with considerable precision by putting a tone current on the wire and following along the surface of the ground with an exploring coil device described in another article.* The location of faults in buried wire also involves some problems, which are different from those experienced with cable circuits but experiments have indicated that established methods may be adapted to this new use with an acceptable degree of precision.

Since only a few hundred miles of buried wire circuits of the type described have actually been installed and put into service, it is recognized that many problems may yet arise and that this type of plant should still be considered as in a trial stage. It is, for example, not known to what extent burrowing rodents such as gophers may cause difficulties. Soil erosion may also introduce problems not as yet clearly visualized. On the other hand there should be avoided, by placing the wire under ground, many troubles due to wind, ice and

*Record, *August*, 1936, *p.* 382.

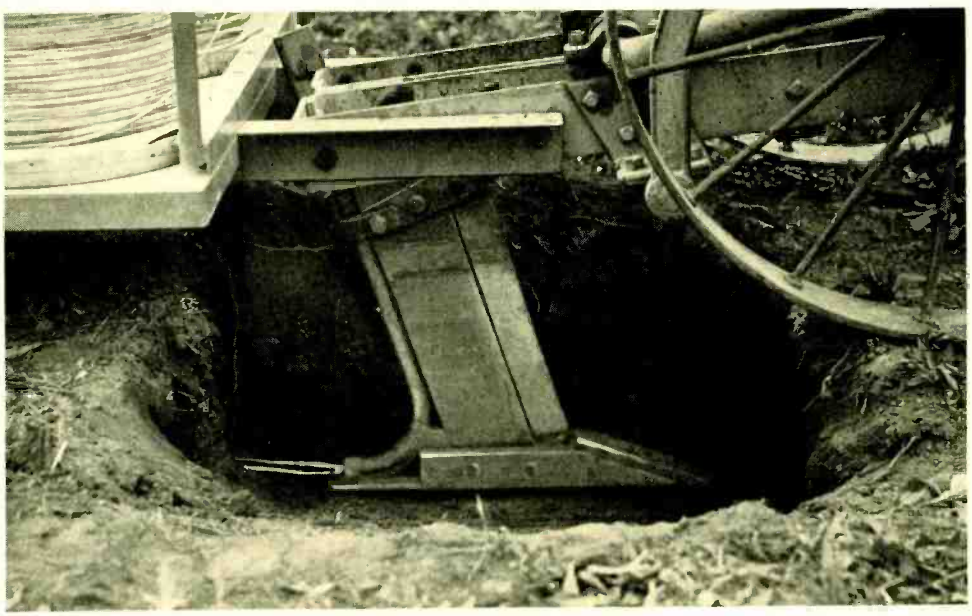


Fig. 4—Wire plow with ground cut away to show wire passing through plowshare

tree interference which are peculiar to open wire construction, involving such things as broken insulators, broken poles and crossed or broken wires. Buried wire should also, in general, be free from lightning troubles when properly protected at its junctions with exposed circuits. Considerations of this kind will be largely controlling in determining the eventual field of use for the buried type circuit, but present indications are that many locations may be found where this type of construction will prove economical.

Members of Laboratories Contribute to Electrical Engineers' Handbook

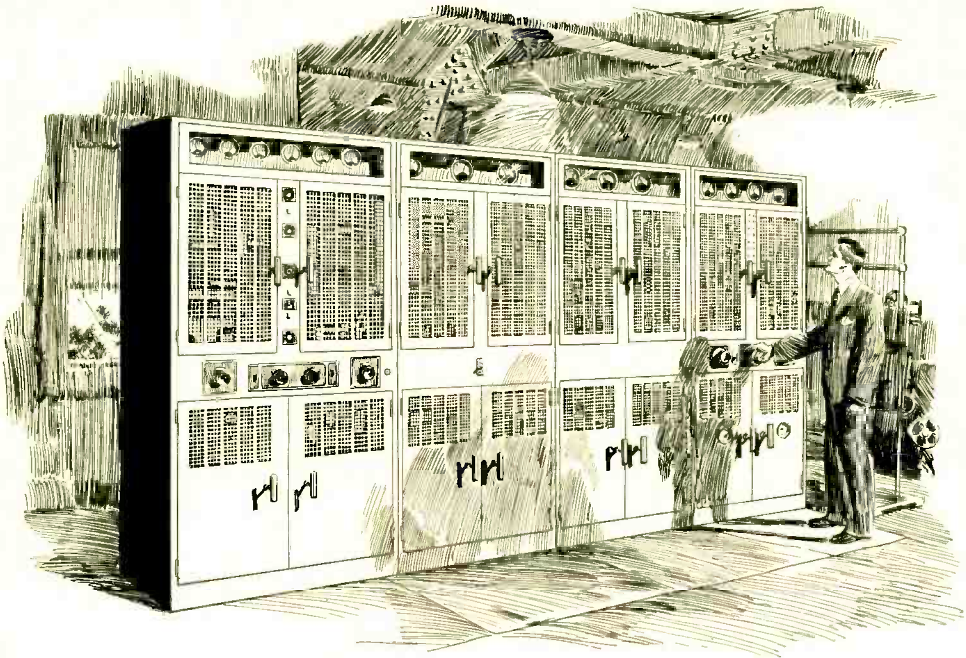
The third revised edition of the "Electric Communication and Electronics" section of the "Electrical Engineers' Handbook," prepared by Harold Pender and Knox McIlwain, has recently been published by John Wiley and Sons. Sections contributed by members of the Laboratories follow:

Photo-Responsive Devices by H. E. Ives; Mechanical Optical and Magnetic Recording and Reproducing of Sound by H. A. Frederick and A. C. Keller; Electrical Wave Filters by T. E. Shea and C. E. Lane; Radio Antennas by G. C. Southworth.

Transmission in Space by J. C. Schelleng; The Sense of Hearing, Speech and Music, and Effects of Distortion on Speech and Music by J. C. Steinberg.

Frequency Measurements by W. A. Marrison; Measurement of Primary Electrical Quantities by W. J. Shackelton and J. G. Ferguson; Wire Transmission Measurements by F. H. Best; Measurements of Transmission Through Space by R. K. Potter; Wave Analysis by E. Peterson and T. G. Castner; and Radio Telephone Systems by A. A. Oswald.

In the preface to this third edition Mr. Pender and Mr. McIlwain said "The editors' thanks are due to the many well-known and busy men who have contributed textual material, both for their unselfish efforts to make this a reliable reference work and for their patience with editorial vagaries; . . . and to John Mills, Direction of Publication, Bell Telephone Laboratories, for his criticism and aid in the organization of the book."



A New 5-kw Broadcast Transmitter

By L. G. YOUNG
Radio Development

RECENT developments have resulted in a new Western Electric five-kilowatt broadcast transmitter, called the 355D1. The rapid trend toward higher quality in radio transmitters has already resulted in the "high-fidelity" transmitter—a designation descriptive of quality and well merited by performance. High-fidelity transmitters of various ratings have already been developed by the Laboratories, and the 355D1 is also distinctive in this respect. Its chief contribution to the radio art, however, is the attainment of high-fidelity characteristics with simplified apparatus and lowered cost. To a large extent this has been brought about by the use of stabilized feedback, which has permitted the new transmitter to be completely a-c operated, and—with other improvements—has made available a transmitter of highest quality that is yet low in price and easily maintained.

The development of stabilized feedback marked the beginning of a new era for radio transmitters. While the audio input to a radio transmitter may be of very high quality, there is always a certain amount of distortion and noise produced by or picked up in the transmitter circuits themselves. If the filaments of the tubes were heated by alternating current, one of the major disturbances would be a hum picked up from the power supply circuits. For this reason it has been common practice in the past to operate all filaments of the larger transmitters on direct current to avoid this form of disturbance and the remaining noise and distortion have been kept satisfactorily small by careful design. Stabilized feedback, by permitting an automatic reduction of unwanted components, provides an effective tool for the reduction of all forms of distortion arising in the transmitter.

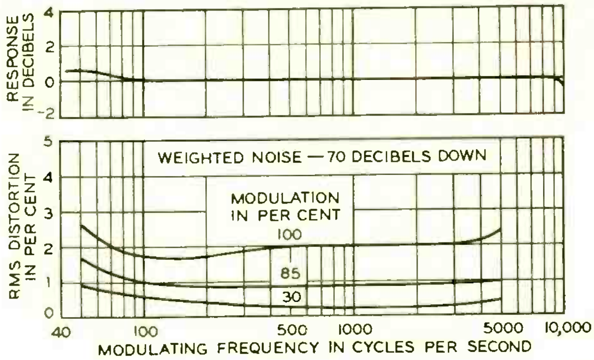


Fig. 2—Response and distortion characteristics of the 355D-1 transmitter

In the stabilized feedback circuit, a small portion of the transmitter output is rectified, to obtain the voice-frequency envelope, and then fed to the grid circuit of the first audio amplifier in phase opposition with the original speech input. This gives to the input all the noise and distortion components added by the transmitter, but in the opposite phase. This reversed phase noise and distortion as it passes through the transmitter can be made to reduce the noise and distortion in their normal phase to a degree which is measured by the amount of feedback applied. The desired or signal components are also reduced to the same degree but this may be offset by increasing the level of the speech input signal. The amount that the speech input has to be increased to bring the signal output of the transmitter to the same level as it had before applying feedback is a measure of the amount of feedback incorporated in the circuit. Thus if a transmitter requires a zero level input without feedback to fully modulate it and a plus twenty level with the feedback circuit connected, it may be said that twenty db of feedback is employed and that the distortion and noise will be twenty db better than it is without feedback.

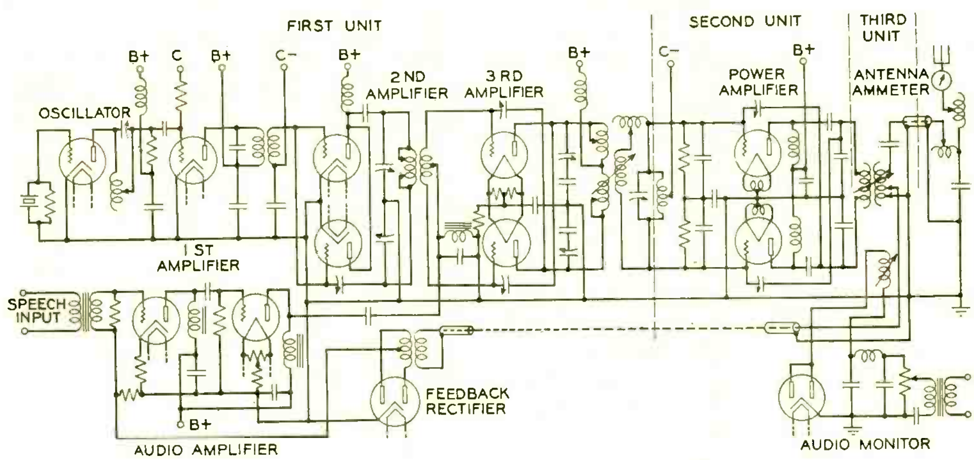


Fig. 1—Simplified schematic of the 355D-1 radio transmitter

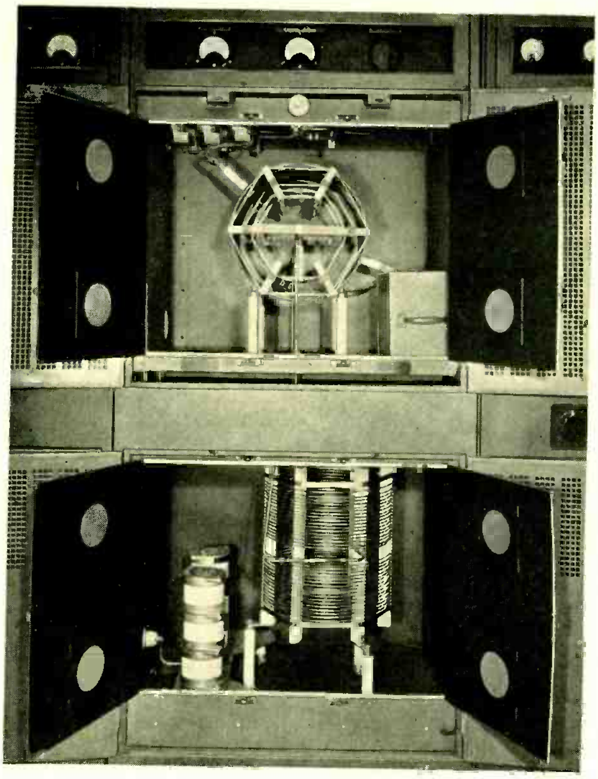


Fig. 3—Radio-frequency coupling unit of the five-kilowatt radio transmitter

rectifier employs six of the 315A tubes, and is rated to deliver 1.7 amperes at 11,500 volts. This is the first application of this low-priced tube, which is designed primarily to reduce the cost of furnishing direct current at voltages as high as 12 kilovolts.

Another simplification in the new transmitter is the omission of the one-kilowatt amplifier unit. One complete unit, including tubes and power supply, has been omitted, thus lessening the cost of the transmitter and decreasing the space required. Many stations are licensed for operation at 5 or 2.5 kw during the day and at 1 kw during the night. With the D-96847 transmitter, this change was accomplished by automatically switching the antenna from the output of the 5 kw amplifier to that of the 1 kw amplifier. With the elimination of the 1 kw amplifier, this method of changing the output power cannot be employed. Instead, the plate and bias voltages and the radio-frequency grid excitation of the final amplifier are reduced to the proper values to secure the lower output. This change is made automatically merely by the operation of a switch on the control panel. So far as the operation of the transmitter goes, therefore, there is no other change necessary in this respect.

This new transmitter is similar in its general features to the D-96847 already described in the Record,* but the use of alternating current for the filaments has made it possible to eliminate the motor-generator set. Its place is taken by simple transformers to reduce the alternating current supply voltage to a proper value for application to the filaments. Transformers are not only much less expensive than motor generators, but require no attention during operation, and their use therefore represents an appreciable simplification. A further distinguishing feature of the new transmitter is the use of the 315A mercury-vapor rectifier tube in the high-voltage rectifier circuit. This

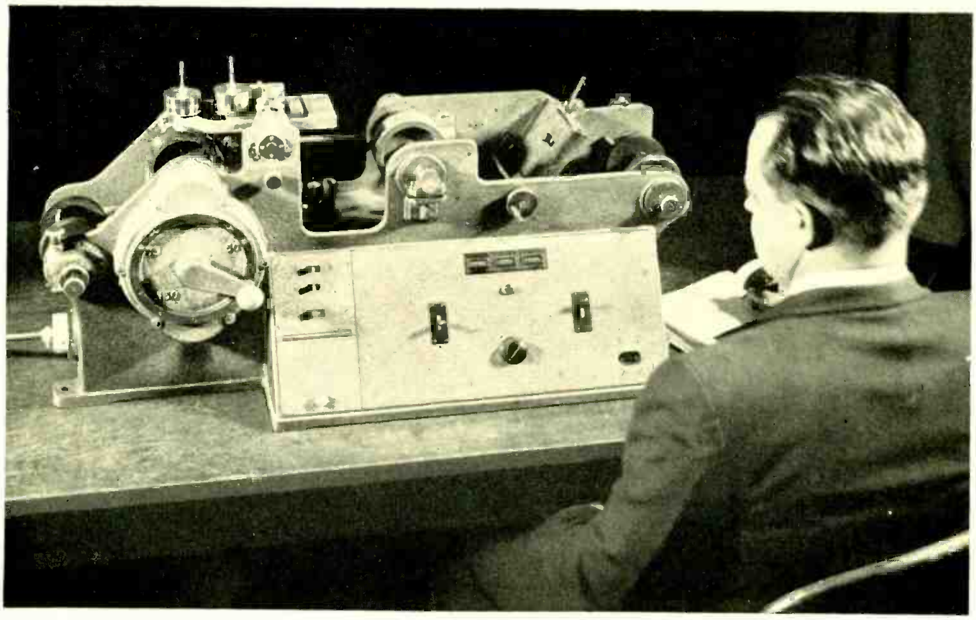
A simplified schematic diagram of the 355D-1 transmitter is given in Figure 1. Only twenty-seven tubes are employed in the complete transmitter, which represents a substantial reduction as compared with other equivalent transmitters. A crystal-controlled oscillator with a buffer and

*Record, *August*, 1935, *p.* 374.

a carrier amplifier, and two audio amplifiers supply the modulating amplifier. This latter amplifier works directly into the final amplifier, which employs water-cooled tubes. The feedback circuit with its rectifier is shown in the lower part of the diagram. Since the oscillator-modulator unit is operated at constant level regardless of the power output of the final stage, it is necessary to provide some means for keeping the amount of feedback constant when the output is changed. This is accomplished during the process of switching from one power to another by a relay which inserts just the right amount of resistance in the feedback circuit. One of the great advantages of the feedback circuit for the elimination of noise and harmonic distortion is that it is entirely automatic in its operation. Its satisfactory action does not depend on periodic calibration or adjustment, nor upon the precision with which the apparatus can be built, but is inherent in normal operation.

A sketch of the new transmitter, the first of which was installed at station WSAI in Cincinnati, is shown at the head of this article. The right-hand unit contains the control circuits, the signal lights which indicate the operating status of the transmitter at a glance, and the grid-bias rectifier for the final amplifier stage. The unit on the left, called the oscillator-modulator unit, contains the preliminary radio-frequency apparatus with its own power-supply equipment, and is—in fact—a complete 100-watt radio transmitter in itself. Its function is to supply a modulated radio-frequency voltage to the grids of the water-cooled amplifier stage, where the power level is raised to either one or five kilowatts. The two middle units house the two water-cooled tubes of the final stage, and the facilities for tuning the plate circuit of these tubes. The approximate division of the radio apparatus into the three units is indicated in Figure 1.

The high quality of the new transmitter is indicated by Figure 2. From the upper curve it may be seen that the output is essentially flat from 40 to 10,000 cycles. The noise contributed to the signal by the circuits of the transmitter is approximately 70 db below the signal level obtained at 100 per cent modulation. The per cent distortion, even at 100 per cent modulation, is so low as to be practically negligible. Tentative requirements of the Federal Communications Commission specify that the distortion should not exceed 10 per cent at 95 per cent modulation, nor 5 per cent at 85 per cent modulation. Corresponding figures for the 355D-1 transmitter at 400 cycles are 1¾ per cent and 0.8 per cent respectively. This margin of improvement, made possible by the advanced design and performance of the new transmitter, is so large that it is not likely to be wiped out by any future raising of the standards.



A Machine for Testing Enameled Wire

By H. H. STAEBNER
Telephone Apparatus Development

BAKED enamel, applied in a continuous uniform coating, is one of the most economical materials in use for insulating copper wire. For a given thickness it has unusually high dielectric strength and insulation resistance, and these properties are almost independent of variations in atmospheric humidity. Even the best commercial grades of enameled wire, however, are subject to irregularities; control tests on samples of the product are required to insure that the coatings shall remain continuous, uniform and effectively free of defects after the wire has been used in the manufacture of apparatus. The continuity of the coatings has usually been determined by running the wire through a mercury pool and recording the number of electrical contacts between the wire and the mercury. This method detects the bare spots but gives no indication of hidden defects in the enamel.

Heretofore reliable means for determining quantitatively the physical properties of the finished product, particularly the hardness, adherence, and general resistance to abrasion of the enamel coating have not been available. To satisfy this need the Laboratories have developed a testing machine by means of which it is possible to make simultaneously two improved types of physical tests on enameled wire samples. One detects spots of low insulation resistance or actual holes through the enamel film, and the other determines the mechanical strength of the insulation by scraping it. The results are automatically and continuously recorded.

The machine for making these tests is shown in the headpiece. The wire to be tested is pulled continuously from a spool through the testing devices without stretching it and the tested wire is wound on a spool again. The apparatus for carrying and testing the wire is at the top of the machine and the driving motor and the electrical apparatus for detecting the faults and recording the results of the tests are housed in the cast aluminum base. The wire to be tested is threaded through the machine as diagrammed in Figure 1. On the top of the machine, in addition to the necessary mechanism for holding the supply spool, distributor, and take-up spool, there are two metal drums about which the wire is strung in three passes. These drums are mechanically driven at the same speed to aid in pulling the wire under the scraper without stretching it. The "testing drum," at the left, is ground to a smooth cylindrical surface and the middle pass of wire on this drum is subjected to the scraping action of a sapphire edge ground accurately to a very small radius. The scraper is held in a pivoted metal rack so that the pressure with which the scraping edge bears down on the wire may be accurately controlled by placing known weights on the rack and the pressure required to scrape off the enamel as the drum revolves may thus be determined. A photograph of this part of the machine appears as Figure 2. By means of the gear-changing lever which is shown there, a suitable speed for the particular sample of wire under test may be chosen.

Before the wire reaches the testing drum it passes between two rollers electrically charged with respect to the wire in such a way as to detect "pin holes" or insulation faults in the enamel. This "roller test," in the form in which it was originally developed, has already been discussed in the Record.*

On the base of the machine, as shown in the headpiece, there are three registers, designated the counter, scraper, and roller registers. The electrical circuit operating the counter register is closed by a switch operated by a commutator cam on the shaft of one of the drums about which the

*Record, *April*, 1932, *p.* 287.

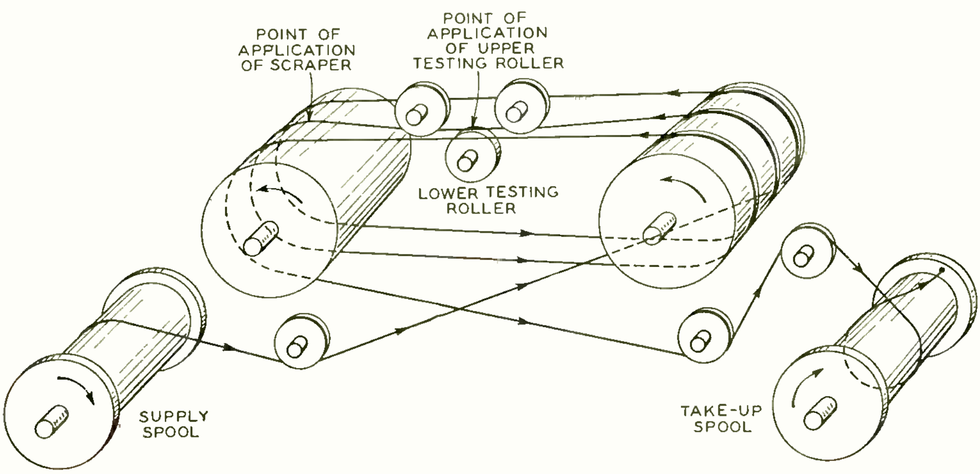


Fig. 1—*Wire threading diagram for the enameled wire testing machine*

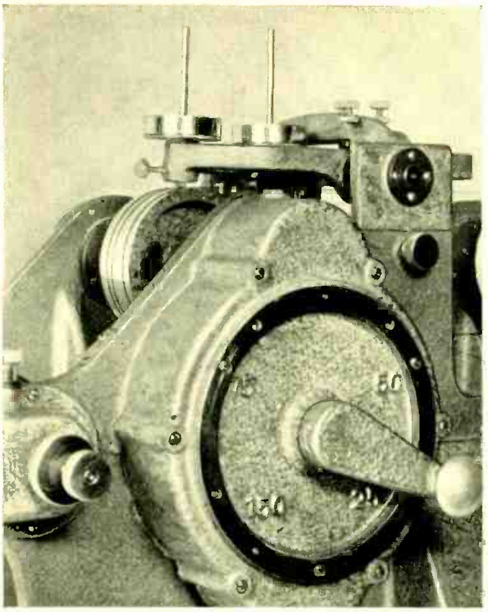


Fig. 2—The sapphire scraper bears on the central turn of the wire around the testing drum

wire passes. The circumference of the drum is one foot, and the cam has six lobes. Thus the register operates six times for each foot of wire, and records the total number of two-inch lengths of wire passing through the machine.

The scraper register records the number of two-inch lengths of wire on which the enamel has been scraped off. In the scraper circuit, Figure 3, are two mercury pools about a quarter inch apart located on the frame of the machine, in such a position that the scraped wire passes through the two pools in succession after leaving the testing drum. These pools consist of steel cups lined with rubber tubing and filled with mercury. The rubber tubing is slit in order that the wire can be drawn through the two pools in series, with the wire immersed properly in the mercury.

The scraper circuit also contains a vacuum tube, supplied with a plate potential of 110 volts through the other side of the switch which operates the counter register. This tube has a negative grid bias so that current does not normally flow through the register, which is in the plate circuit. If a bare spot occurs on the wire, long enough to short-circuit the two pools of mercury, the grid bias is reduced and the scraper register operates once and opens the circuit by means of an associated relay. The circuit remains open until the next break and make of the commutator reinstates it, and thus the scraper register can operate once at most for each two-inch length of wire. The percentage of wire scraped bare can accordingly be obtained directly as the ratio of the number of counts on the scraper register to the number of counts on the counter register.

The roller circuit is similar to the scraper circuit, except that the plate potential is not interrupted by the commutator, and accordingly the roller register operates as many times as defects in the enamel insulation allow the charged rollers to complete an electrical circuit through the wire under test.

A record of the positions of the defects along the wire as well as of their

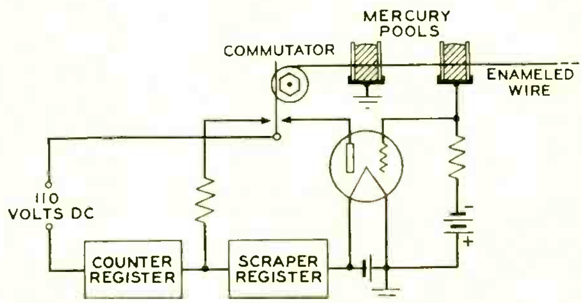


Fig. 3—Simplified schematic of the counter and scraper recording circuit

number is obtained by means of a special recorder which may be connected to either the scraper or roller test circuit. The recorder pen draws a straight line on the paper chart until a defect operates the test circuit. The circuit in turn operates a stepping magnet pawl and ratchet, which pushes the pen one step to the right. The pen then continues to draw a straight line until another defect pushes it one step further to the right. The resulting record is a series of irregularly spaced steps whose positions on the recording chart indicate the positions of the corresponding defects along the wire (Figure 5). In case the recorder is connected to the scraper circuit the percentage of wire bare is proportional to the ratio of the distance which the pen has been displaced to the right, to the perpendicular distance which the pen has traveled along the chart. The abscissa of the end of each diagonal line is the percentage of wire scraped in that particular thirty-four-foot length. As the pen approaches the right side of the chart the mechanism may be

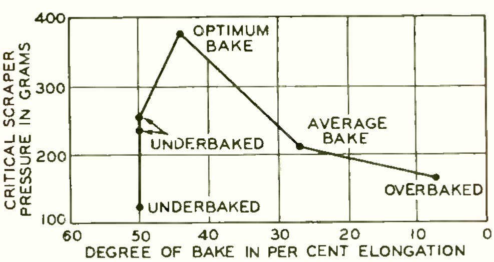


Fig. 4—Degree of baking related to critical scraper pressure

stopped and the pen replaced manually to the left side of the chart by operating a reversible distributor.

In performing the scraper test, the pressure of the scraper on the wire is varied, and sufficient wire is run under the scraper at each weight to

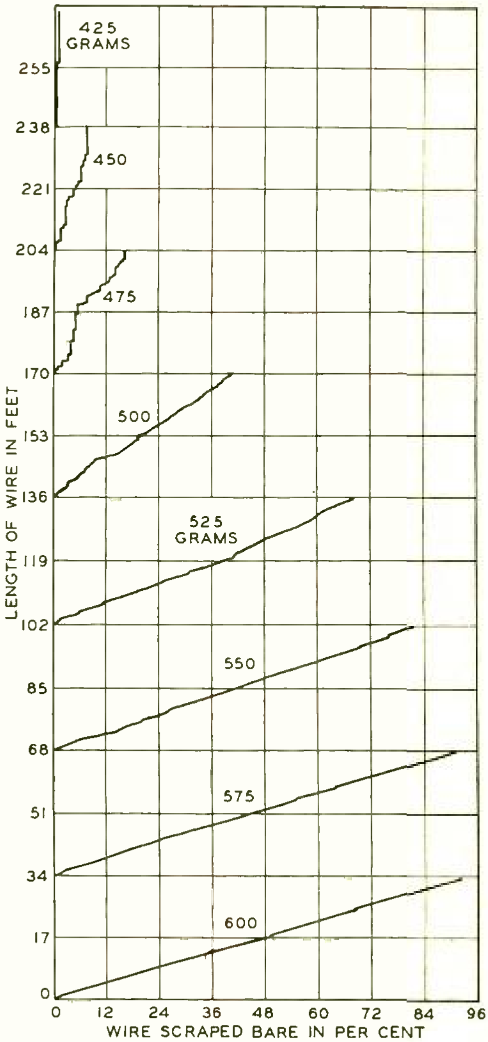


Fig. 5—Typical plot obtained by connecting the automatic recorder to the scraper circuit. The abscissa of the end of each diagonal line is the percentage of wire scraped bare in that thirty-four-foot length

determine the per cent of wire scraped bare at each pressure. The data obtained in the scraper test are plotted as in Figure 6 to show the relation between increasing scraper pressure and the corresponding percentage of failure of the enamel.

The quality of enameled wire as determined by the scraper test is measured most conveniently in terms of a "critical pressure" defined as the pressure at which ten per cent of the length of the enameled wire is scraped bare. This point was chosen because the majority of curves showing the relation between pressure and per cent scraped wire have a well defined knee at about this point for most types of enamel tested. Above this point the curves rise with a characteristic slope which is approximately the same for all samples of wire and roughly proportional to the increase in pressure.

The success with which this testing machine has been used to determine the quality of enameled wire produced under various conditions of manufacture is shown by the averages of data plotted in Figure 4 to illustrate the effect of varying the degree of bake upon the resultant critical scraper pressure. The degree of bake is expressed in terms of the per cent elongation which the enamel will stand without cracking. It will be observed that the critical scraper pressure rises rapidly as optimum conditions are approached, and falls off slowly as the enamel is overbaked.

The merit of this scraper test for evaluating the quality of enameled wire, such as that represented in Figure 4, has been confirmed by winding the wire into experimental coils which were then subjected to extensive performance tests to determine their characteristics. In these tests a much greater useful life of the windings was indicated for the enameled wire having the maximum scraper pressure than for coils wound with enameled wire having lower scraper pressures caused by baking the enamel under conditions less favorable.

The scraper test machine thus enables those properties of enamel such as hardness, toughness, and adherence of the film to be directly evaluated in terms which determine its ability to withstand the stretching, abrasion, and other abuse which it may receive during manufacturing and coil winding operations.

Experience with this machine indicates that it may be successfully employed to measure the adherence and continuity of the enamel coating on wire in a quantitative manner and, in addition, on a reproducible basis.

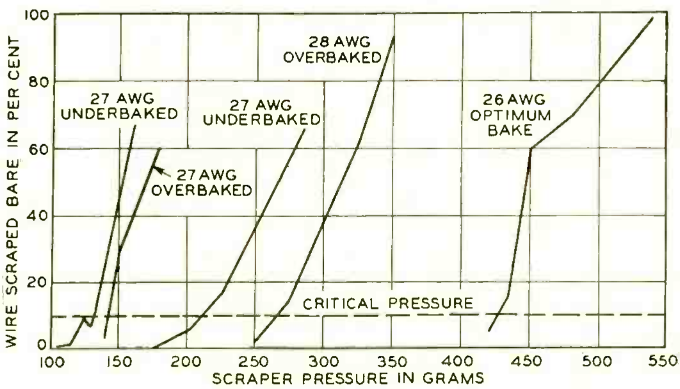
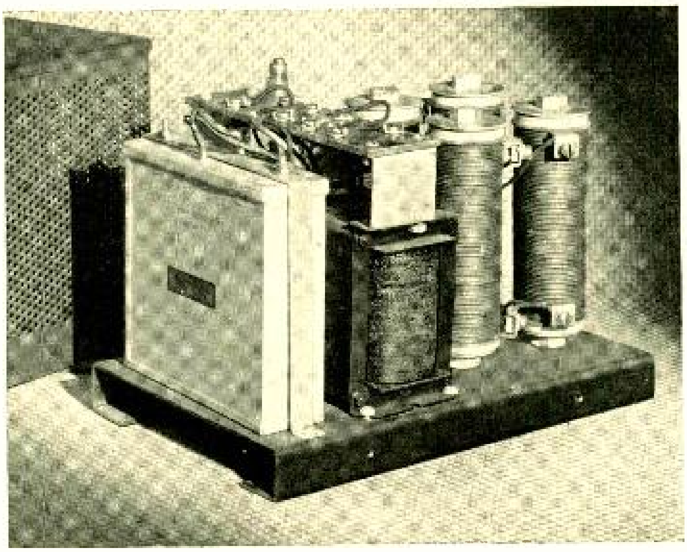


Fig. 6—Enameled wire shows wide variations in the pressure required to scrape it bare



Copper Oxide Rectifiers for Telephone Power Supply

By M. A. FROBERG
Equipment Development

COPPER oxide rectifiers are being used in increasing numbers in the telephone system to operate relays and signals and to provide direct current for charging small storage batteries where the demand for current is not great. The use of these rectifiers has heretofore been limited largely to private branch exchanges and similar small switchboards, but has recently been extended to individual subscribers' equipment to supply direct current for intercommunicating installations and auxiliary signals and to operate the relays and selectors in subscribers' teletypewriter stations. These small exchanges and subscribers' locations are usually so far from the central office that the power required, although relatively small in amount, cannot be economically supplied over cable pairs. The demand for this type of rectifier has become such as to make it desirable to develop designs that are specifically intended for telephone use.

The rectifying element of this type of rectifier, called a varistor, consists of oxidized copper discs. These age to a certain extent with use with the result that their electrical characteristics change appreciably. The change which most concerns the design of rectifiers is the increase in forward resistance. When this is excessive it reduces the output of the rectifier below that required by the circuits which it supplies and shortens its useful life. This aging effect increases rapidly with increase of temperature and for this reason power rectifiers must be

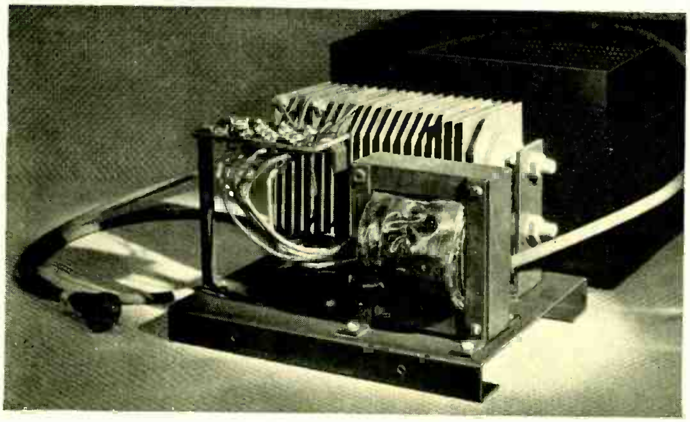


Fig. 1—Rectifier which operates the selective calling equipment in some teletypewriter systems

The rectifier illustrated in the headpiece was designed to supply 120 volts d-c for operating the local circuits at certain types of teletypewriter stations. It has in addition to a transformer and varistor a filter to suppress the pulsations of the rectified current so that they will not cause false operation of the local circuits that are involved in the system.

designed to operate at comparatively low temperatures. In designing such rectifiers perforated metal is used for the sides and in some cases for the top of the housing. The varistor must also be located so as to permit free circulation of air around the ventilating fins with which the rectifying units are usually equipped.

Where the voltage limits within which the rectifier must operate are comparatively close it is necessary to provide a number of taps on the primary or the secondary winding of the power transformer to permit increasing the a-c voltage applied to the varistor as it ages and in that way maintain the output voltage within the prescribed limits. The taps on the transformer are also necessary when the same rectifier is to be used for several different switchboards, if there is an appreciable difference in the current required by them.

In some cases the same type of rectifier is suitable for several different services. Such a rectifier, Figure 1, which delivers 1.2 amperes at 24 volts, is used to operate the selective calling equipment in some teletypewriter systems and it is also used to operate the intermediate toll-line ringers when a-c repeaters are installed on long lines. The electrical characteristics required for both services are the same.

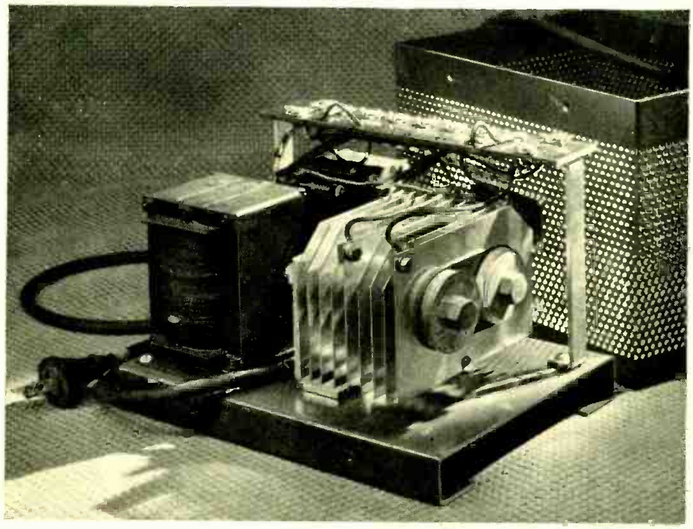


Fig. 2—Rectifier for charging storage batteries for small switchboards and to charge ringing batteries, grid batteries and similar small low-voltage batteries in central offices

Two rectifiers have been developed for charging storage batteries. One which has a rating of 0.35 amperes at 22 volts or 0.5 amperes at 17 volts is used for the batteries of small switchboards and to charge ringing batteries, grid batteries and similar small low voltage batteries in central offices. This rectifier is shown in Figure 2. The second of these rectifiers differs appreciably both in rating and appearance from those which have thus far been described. This unit develops 6 amperes at 10 volts and is used to supply a trickle charge for the emergency cells of large central office batteries. These cells are installed for standby service and are added to the main battery in case of failure of the charging machines. Rectifiers are used to keep them fully charged so that they will be available at any time if the commercial power service fails. The batteries are so large in some cases that it requires several rectifiers operating in parallel to supply the necessary charging current. This rectifier was designed for mounting on a power board with other power-control apparatus and it is equipped with a voltmeter and ammeter. Radial switches are provided for selecting the proper transformer taps to give the required voltage and current output. This rectifier is generally supplied for use on 190-250-volt 60-cycle a-c. power lines, but may also be furnished for 105-125-volt service. It is illustrated in Figure 3.

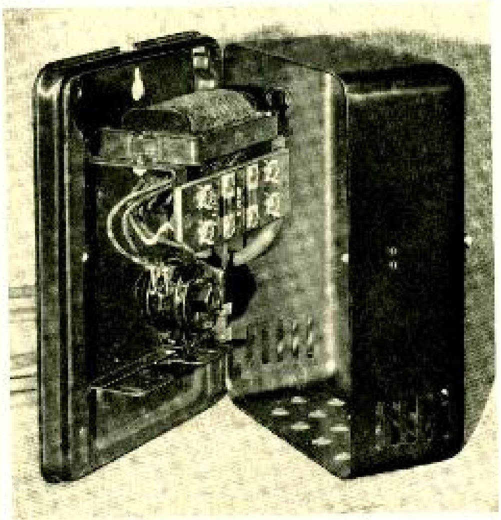


Fig. 4—Rectifier mounted in subscriber's bell box used to operate audible and visual auxiliary signals remote from the telephone

The smallest rectifiers thus far designed for telephone apparatus are for use with the regular subscriber's sets and can be mounted under desks or tables or in similar restricted spaces. Figure 4 shows a subscriber's bell box in which a transformer and varistor has been mounted to supply direct and alternating current at low voltages. The current from this rectifier is used to operate audible and visual auxiliary signals when it is necessary to

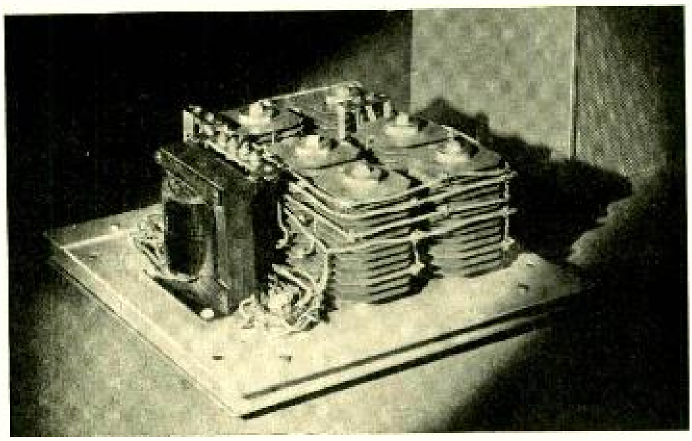


Fig. 3—Rectifier used to trickle-charge emergency batteries in large telephone central offices

provide such signals in locations remote from the telephone.

A rectifier which is the same in physical appearance as that shown in Figure 1 is used to supply current for operating the relays and signals of key equipments when cable pairs are not available to supply the power. It consists of a transformer which connects directly to the 105-125-volt 60-cycle a-c. power supply by means of a cord and attachment cap, an oxidized copper varistor for rectifying the a-c; a noise suppression filter to prevent disturbances from the rectified current from affecting the telephone transmitter supply and a retardation coil to smooth the ripple in the relay supply. An additional secondary winding on the transformer provides low-voltage alternating current for ringing. The external leads to the key equipment units are connected to a terminal board which also mounts the fuses for protecting these leads. The rectifier is arranged for wall mounting but can also be conveniently attached to a relay rack or power board or stood on its base. The cover is removable for fuse replacement and the sides may be taken off for adjustments and repairs.

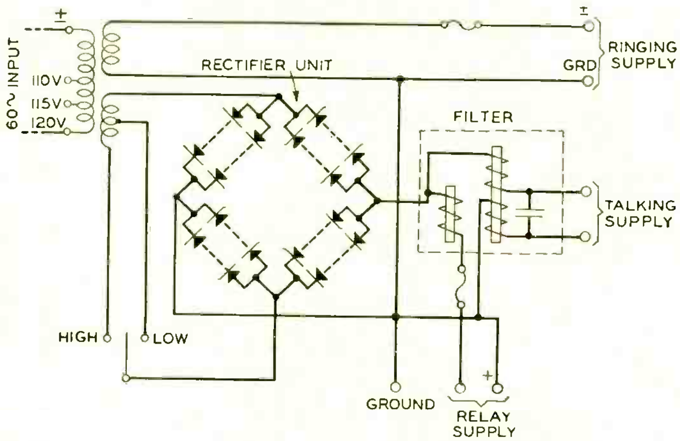


Fig. 5—The rectifying element shown here comprises two sets of discs in parallel in each of the four arms of the circuit. The filter consists of a retardation coil and a condenser

The elements of this circuit which are fundamentally the same as in all of the rectifiers described here are shown in Figure 5. The rectifier unit has two sets of discs in parallel in each of the four arms of the circuit. The output of the transformer is connected to the rectifier so that direct current will be available both for relays and talking supply. Independent taps are also provided on the transformer to give alternating current for ringing. This gives a relay supply of from 15 to 33 volts, d-c, when connected to loads from 30 to 250 ohms and a talking supply of from 2.5 to 4.5 volts for loads of approximately 30 ohms. The ringing supply varies from 16 to 21 volts for loads up to 16 ohms. The filter that is used in the talking supply circuit consists of a retardation coil and a condenser.

Copper oxide rectifiers, of which those described here are representative, have been found to give effective service for many different purposes where small currents are required in the telephone plant and their use in this connection is increasing rapidly.

Apparatus Card Catalog

By C. R. BARNEY
Specifications Department

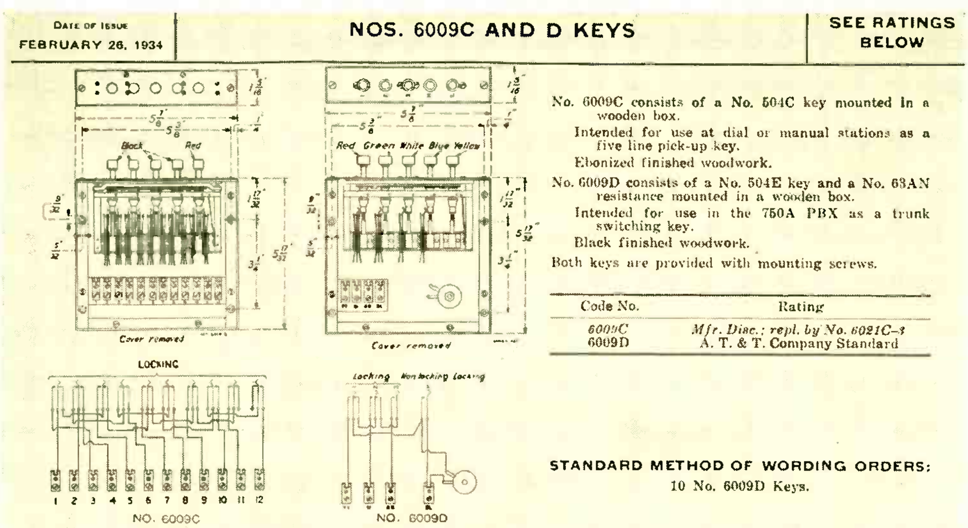
PREPARED and issued by the Laboratories, the Apparatus Card Catalog differs from the more usual type of catalog, and probably has the distinction of being the only one of its kind in existence. The more usual commercial catalog is designed as an advertising medium to stimulate sales as well as to give information respecting the product, while our Apparatus Card Catalog is issued for use primarily within the Bell System, where advertising is not required since the apparatus and its quality are known. It goes to the operating companies, to the various manufacturing branches, and to many departments in the Laboratories, and its principal object is to provide a compact source of technical data and of information as to size, appearance, and purpose of the thousands of pieces of apparatus that comprise the Bell System plant. Price information is supplied through separate price lists issued by the Western Electric Company, and is not incorporated on the apparatus cards.

The apparatus card catalog has many uses, but chiefly it serves the Bell System in connection with engineering, merchandising, ordering, and accounting. On January 1, 1936, there were 594 of these catalogs in the United States. Each catalog is numbered serially to establish its identity at all times, and the number appears on each card.

Since the catalog lists more than twenty-five thousand different pieces of apparatus, one of the first requisites is that the apparatus listed should have names and codes that will facilitate the grouping of similar apparatus and insure proper identification. So far as practicable, the names used are descriptive of the class in which the apparatus falls, but the codes are generally arbitrary. Some of the more common names are cords, keys, relays, and subscriber sets. The frequency with which the names and codes appear on correspondence and orders, and their use on drawings where space is rather limited, make it quite desirable that they be short and easy to remember.

The codes serve to designate the subdivisions of the named apparatus, and are composed of combinations of numerals and letters, such as the 653AR subscriber set, the R156 relay, and the A2AF key. The first part of the code denotes the type or general design of the apparatus, and the other part or parts denote the various modifications. The letters I, O, Q, V, X, and Z are rarely or never used because of possible confusion with other letters or figures. Thus "I" and "O" are similar to one and zero, "Z" and "Q" are easily mistaken for two, and "V" and "X" may similarly be ambiguous. This leaves twenty letters for codes; when more than twenty are needed, two letters are employed, making 420 combinations possible. When it is likely that more than 420 codes will be needed for any one type, a letter is employed to designate the type, and numerals from 1 up as required are added to denote the various modifications. Three or four figures are not objectionable in a code, but more than two consecutive letters are difficult to remember, and are therefore not usually employed. The need for such large numbers of codes is illustrated by such apparatus as relays, for some types of which there are over two thousand coded units.

In coding new types of apparatus, consideration is frequently given to the use of significant codes, that is, codes in which certain of the characters have a descriptive meaning. In the codes S3A and S3B as applied to cords, for example, the letter S signifies switch-


DATE OF ISSUE FEBRUARY 26, 1934

NOS. 6009C AND D KEYS

SEE RATINGS BELOW

No. 6009C consists of a No. 504C key mounted in a wooden box.

Intended for use at dial or manual stations as a five line pick-up key.

Ebonized finished woodwork.

No. 6009D consists of a No. 504E key and a No. 63AN resistance mounted in a wooden box.

Intended for use in the 750A PBX as a trunk switching key.

Black finished woodwork.

Both keys are provided with mounting screws.

Code No.	Rating
6009C	*Mfr. Disc.; repl. by No. 6021C–3*
6009D	A. T. & T. Company Standard

STANDARD METHOD OF WORDING ORDERS:

10 No. 6009D Keys.

This card is the property of the Western Electric Company, Inc., and is a part of the TELEPHONE APPARATUS CATALOG (of the number indicated at the left). It is held subject to the Company's order at all times and must not be removed from the catalog of which it forms a part except on the Company's instructions. Printed in U.S.A.

Catalog No. 219

Fig. 1—A typical apparatus catalog card

board cords, the numeral 3 signifies three conductors; and the final letters A and B cover various combinations of miscellaneous features such as external covering and conductor insulation. In general, little benefit is derived from codes of this kind, since experience shows that very few of those having occasion to use the codes understand the meaning of the significant characters. Most schemes for significant coding, moreover, eventually lead to difficulties, since future growth and development are likely to reveal unforeseen coding problems.

Information regarding the various pieces of apparatus listed in the catalog is given by line drawings and description, together with such mechanical and electrical characteristics and schematics as may seem desirable. Detailed information given for different classes of apparatus depends to a large extent upon the nature of the apparatus, its suitability for general use, and whether or not other and better means that do not readily come within the scope or practicability of the Card Catalog are available for distributing information.

All apparatus listed in the catalog is given what is known as a rating, which indicates whether it is in good standing for use on new equipments, whether it should be used only for replacements and additions to existing equipments, or whether it has ceased to be manufactured. Apparatus which is no longer being manufactured is not ordinarily listed in commercial catalogs for distribution to customers. Information on such apparatus, however, is maintained in the Apparatus Card Catalog for reference purposes so long as an appreciable quantity of the apparatus remains in use.

The preparation of the catalog in card form, permits frequent additions and prompt revisions at minimum cost. This is an important feature, since new designs are continually being brought out to meet new conditions, to increase the life or improve the operation, and to reduce costs, so that frequent additions and changes must be made in the catalog information. This is usually done once a month by the issuance of additional cards and the reissuance of such cards as need revision, as new and changed apparatus becomes available for shipment to customers. It is the practice to provide catalog holders with an up-to-date checking list of all the cards making up a complete catalog at the end of each year, thus enabling them to check their catalog and to secure copies of any cards missing.

Relaxation Time in Dielectrics

By. W. A. YAGER
Chemical Laboratories

EVERYONE who has had occasion to experiment with condensers knows that some types absorb a certain amount of electricity which does not come back immediately when the condenser is discharged but which is gradually liberated and accumulates on the plates as a residual charge. This "oozing out" effect has been explained on the assumption that the molecules or groups of molecules of the condenser dielectric are restrained by something analogous to a viscous action and prevented from returning immediately to their normal state at the time of discharge. The amount of this residual charge and the relaxation time or rate at which it is freed are of importance to the telephone engineer because of the large number of condensers which are used in telephone apparatus.

To explain this effect a number of theories have been proposed which start with the assumption that dielectric absorption is due to some action of the molecular structure which takes place uniformly throughout the material. That is, the system is regarded as monodisperse, meaning that the factors which give rise to the absorption are nonvariant within the medium. When this idea is put in mathematical form it leads to an equation for the absorption current and the corresponding relaxation time which involves a single negative exponential term.

It has been found, however, that the behavior of the relaxation effect in many dielectrics is too complicated to be explained on this simple basis. The experimental results indicate that the molecules do not all relax at the same rate and that the residual current involves a combination of relaxation times. Such an arrangement is called a polydisperse system. Mathematically this means that the expression for the relaxation

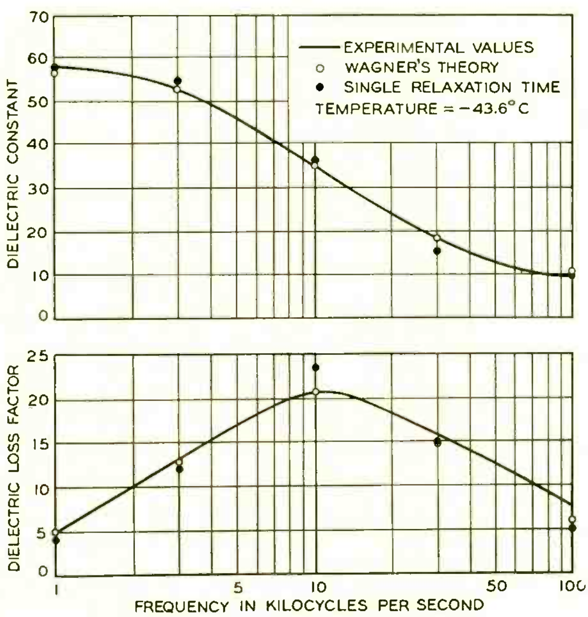


Fig. 1—The changes of dielectric constant and dielectric loss factor with frequency for the organic liquid glycerol are in accord with Wagner's theory of relaxation times

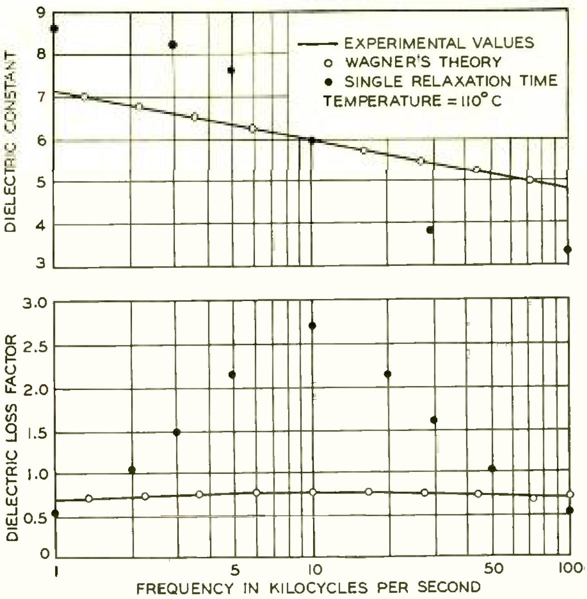


Fig. 2—The dielectric behavior of vinsol

constant and dielectric loss with frequency. This has not previously been investigated and was the subject of the present inquiry. Several dielectrics, both liquids and solids, of different degrees of chemical complexity were chosen to find out if the Wagner theory conformed more nearly to the experimental results than the simple formula. This was found to be the fact. Glycerol was chosen to represent a pure liquid of relatively simple structure. The results are shown in Figure 1 where it will be seen that even in this case the complex theory more nearly conforms to the actual results. The contrast is more obvious, Figure 2, in the case of vinsol, a solid dielectric which consists of a mixture of highly oxidized and

function will consist of the sum of a number of exponential terms, each of these individual terms corresponding to a different relaxation time.

One of the most successful efforts to put this idea into equations is that of K. W. Wagner, who postulated that the number and magnitude of the relaxation times is determined by the law of chance, that is, that it is what mathematicians call a probability function. On the basis of such a function he derived the corresponding absorption equations for the time variation of the reversible absorption current and the frequency variation of the dielectric constant and dielectric loss factor. This enabled him to obtain quantitative agreement between the theoretical time variation of the reversible absorption current and that actually observed in various samples of balata.

A further test of Wagner's theory may be found by comparing the experimental and calculated values of the variations of the dielectric

Fig. 3—Measuring dielectric characteristics

highly polymerized abietic acid and terpenes. Here the difference between the simple theory and the actual results—with which the Wagner theory agrees closely—is very marked.

The results of these studies show that although the simple theory of relaxation times gives fair agreement with the experimental data for dielectrics of relatively simple constitution such as pure liquids, the agreement becomes increasingly poor as the complexity of the dielectric increases. For dielectrics of even moderate complexity the simple formula is practically worthless, while Wagner's equations appear to be applicable to polydisperse systems of all degrees of complexity. This is a helpful advance in the theory of dielectric action.

New York-Philadelphia Coaxial Cable

Illustrations of Splicing Operations Shown on Opposite Page

1. *Starting the coaxial splice, showing sheath cut back to proper point.* 2. *During removal of steel tapes from the ends of the outer conductors of the coaxial units, special clamping tools are used to prevent untwisting of the tapes.* 3. *Rings have been crimped in place over the steel tapes and a special tool is being used to cut the copper tapes to length.* 4. *Showing inner and outer conductors of coaxial units cut to length, with cylindrical insulators in place.* 5. *Soldering sleeve joints in the inner conductors.* 6. *Crimping sleeves in position over the outer conductors.* 7. *Soldering steel tapes and copper sleeves to the outer conductors.* 8. *Boiling out sheath butts and paper insulated quads.* 9. *Splicing paper insulated quads.* 10. *Laying quads around the wrapped coaxial units.* 11. *Final boiling out.* 12. *The completed splice.*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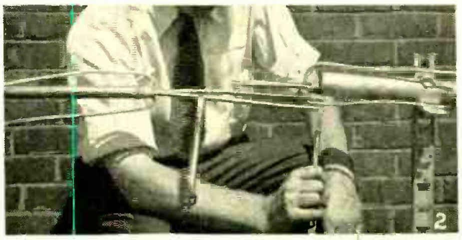
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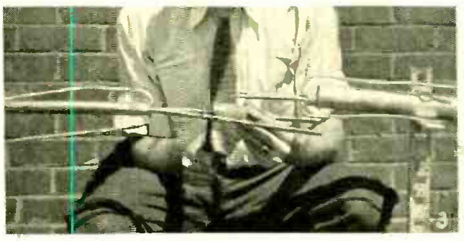
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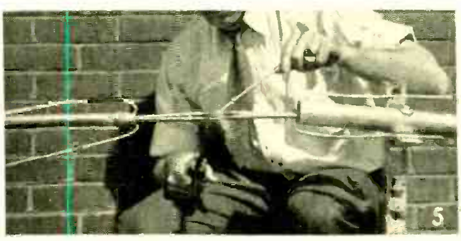
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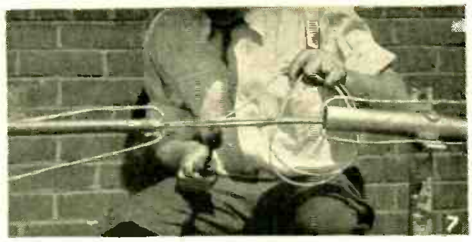
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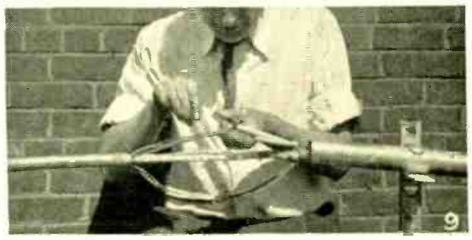
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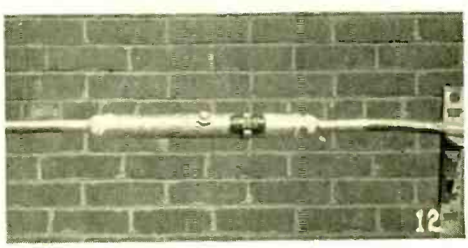
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Protecting Communication Circuits at Power Stations

By L. L. LOCKROW
Protection Development

The use of Bell System wires by power companies, not only for telephone service but for remote control of power station equipment, calls for a high degree of reliability and continuity of service. This is particularly important in the case of pilot wire circuits which are used to assist in disconnecting power transmission lines which have been accidentally grounded.

When power faults occur, the ground potential of nearby power stations may rise considerably above that of the telephone plant which furnishes communication service to the stations. This potential rise is caused by the current which passes from the transformer bank at the station over the line to the fault and back through the earth to the station ground.

At the station the ground current returns from the earth through the station framework, ground rods or buried wires. It may amount to several thousand amperes and cause potential differences of several thousand volts for an appreciable time. The amount of ground potential rise is roughly inversely proportional to the distance from the station ground and the largest differences in ground potentials usually occur within 200 to 500 feet of the station ground. Such potentials may cause a disturbance between the telephone station protector ground and the associated central office ground where the latter is far enough from the power station to be out of the potential field near the station. Without special means of protection, this would cause the telephone circuit protectors to become grounded and the fuses to blow. To prevent the interruption of service which this would cause at a time when that service may be most needed, special devices have been developed.

The neutralizing transformer* provides a means for protecting power station communication lines without danger of even momentary interruption of the services over them from such disturbances. The method of using such a transformer in a telephone or leased wire circuit is illustrated in Figure 3. The transformer consists of a primary winding and two or more secondar-

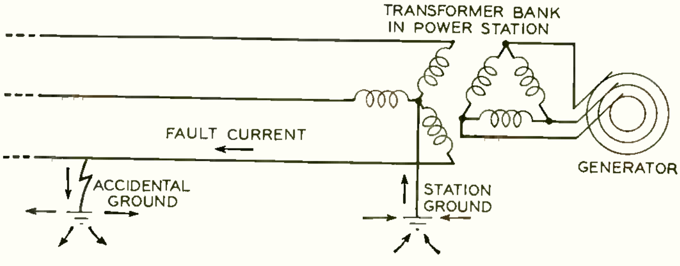

Fig. 1—The ground potential of a power station may be raised for an appreciable time by an accidental fault to ground

*Record, *June*, 1934, *p.* 311.

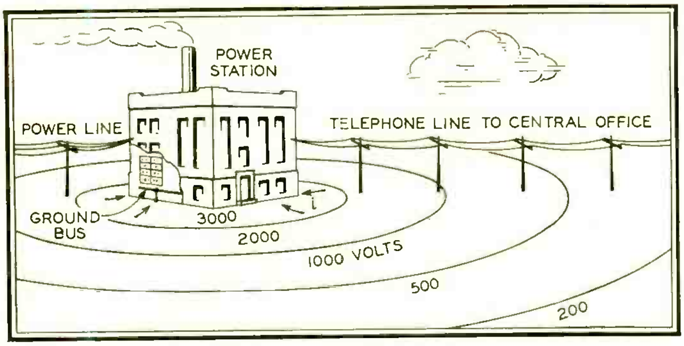

Fig. 2—The potential caused by a fault current is roughly inversely proportional to the distance from the power station

telephone cable and the remote possibility of failure of the neutralizing transformer.

Two neutralizing transformers which are electrically identical have been designed by the Apparatus Development Department, one with cover for outside use and the other without cover for inside mounting. Each has two secondary windings, and will neutralize up to 4,000 volts at 60 cycles. With these arrangements it is practicable to talk over a circuit from the power station to a remote office when the station ground potential suddenly rises as much as 4,000 volts. Under similar conditions it is possible to dial and obtain the correct number.

The arrangement of the transformer in the circuit is the same for magneto or common battery telephones, dial or manual, or for different types of supervisory control and pilot wire circuits. A change in the nature of the facility involves no change in the transformer. Its use avoids the necessity for other special protective measures and the terminal equipment can be wired and handled just as if it were at an ordinary subscriber's station.

ies. The primary winding is connected between the power station ground and the cable sheath, which in turn is grounded, either by bonding to the underground cable or to the central office ground or both. It thus has impressed across it the voltage which tends to disturb the communication wires. By transformer action this voltage appears in the secondary windings. These are connected in series with the communication wires, so that the voltage induced in the windings will neutralize the disturbing voltage which is directly impressed on the communication wires. Where open wire is involved instead of cable, one end of the primary winding is connected to a ground sufficiently remote from the power station to be substantially outside of the field of influence of currents through the station ground so that practically all the station ground potential rise is impressed on this winding. The protectors and fuses shown are standard telephone protection devices, supplied to guard against trouble due to accidental contact of a power wire with the

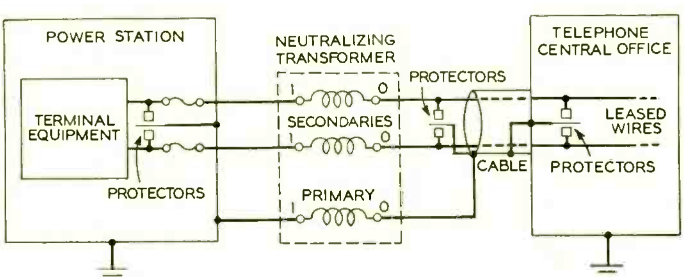

Fig. 3—The neutralizing transformer protects communication lines against serious interruptions by developing a voltage which opposes that due to the fault current

The net unneutralized voltage in the telephone circuit increases with the voltage impressed across the transformer and also increases with the external resistance in the primary circuit. At the full rated voltage and with a primary circuit resistance of 35 ohms, which will not ordinarily be exceeded, the net unneutralized voltage is approximately 80 volts. The use of these neutralizing transformers has no serious adverse effect on the communication line within the voice range and they afford a valuable addition to the devices available for protection against interruption of service where high potentials are encountered at a power station ground.

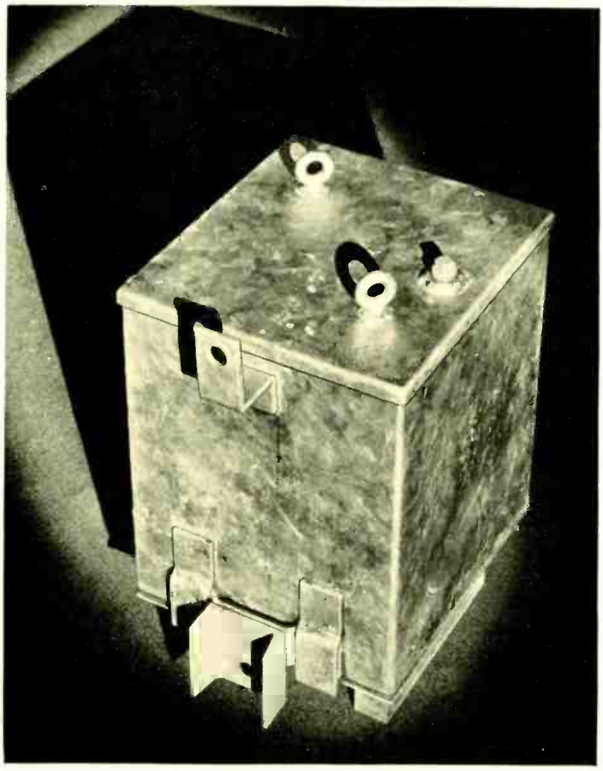

Fig. 4—This transformer, eleven by twelve by thirteen inches in size and 160 pounds in weight, will neutralize voltages up to 4000 volts

Contributors to This Issue

L. G. Young graduated from Carnegie Institute of Technology in 1919 with the degree of B.S. in Electrical Engineering after serving for a short time in the Signal Corps. He joined the Laboratories in the following year and for six years worked on coil design. In 1926 he transferred to the Radio Development Department where he at first was engaged in antenna design. Since 1929 he has been working on the design of high-power radio transmitters.

While a student at Union College, W. A. Yager spent one summer as an assistant in the research laboratory of the General Electric Company in Schenectady working on the development of Carboloy. On receiving the B.S. degree in chemistry in 1928, he joined the Chemical Laboratories. Here he has since been engaged in dielectric and surface-leakage studies, and has most recently been investigating the dielectric properties of various insulating materials under controlled conditions of frequency, temperature and humidity.

M. A. Froberg joined the Equipment Engineering Department of the Western Electric Company at Hawthorne in 1916 after several years in power plant operation elsewhere. He has been engaged in the development of telephone power plant equipment since being transferred to the Laboratories in 1919. The rectifiers described in the present issue of the Record were designed in connection with this program.

L. L. Lockrow joined the American Telephone and Telegraph Company in 1927 after spending several years in teaching and industrial research elsewhere. In 1934 he was transferred to the Laboratories. His work with both organizations has been concerned with theoretical studies and field trials of methods for protecting communication circuits against atmospheric and power line disturbances. Mr. Lockrow received the degree of B.S. from Purdue in 1918, M.A. from Rice Institute in 1921, E.E. from Purdue in 1923 and PhD. from Michigan in 1926. Several patents are held by Mr. Lockrow and he has published papers in the *Physical Review* and the *Astrophysical Journal.*

C. R. Barney entered the Clinton

L. G. Young

W. A. Yager

M. A. Froberg

L. L. Lockrow

C. R. Barney

H. H. Staebner

Street Works of the Western Electric Company in 1904 immediately after graduation from Cornell University with the degree of M.E. in Electrical Engineering. After completing the Student's Course he was associated with the Engineering Department, first in the equipment branch and then in inspection. In 1907 he joined the sales organization, serving later as Hawthorne representative on matters pertaining to new and changed apparatus. In 1913 he came to New York as a member of the Advertising Department to take charge of the work on the card catalog which still occupies him. When the Advertising Department was transferred to 195 Broadway he remained at West Street as a member of the Engineering Department and later of the Apparatus Development Department.

D. A. Quarles

H. H. Staebner received the B.S. degree in Electro-Chemical Engineering from Massachusetts Institute of Technology in 1927 and joined the Technical Staff of the Laboratories in August of the same year. His work has been concerned with the development of central office wire insulation, switchboard and telephone cords and enamel insulated wire for winding coils and for use in cable.

D. A. Quarles received the degree of A.B. at Yale in 1916 and after overseas service in the U. S. Army joined the Laboratories in 1919. Here he was first engaged in transmission studies of circuits and networks. Later he was placed in charge of Inspection Engineering on apparatus products. As Outside Plant Development Director, Mr. Quarles is now directing development work on outside plant products.